

# Exam 1 – EE531

Winter 2014

The test is a take home exam due at beginning of class on Tuesday Feb. 18 (3:30pm EST). Show all work. Be sure to state all assumptions made and **check** them when possible. Please limit active time working on the exam to 10 hours.

1. Consider a thick Si sample doped with  $N_a = 10^{17}\text{cm}^{-3}$ . Light is incident with an absorption depth of  $a = 100\text{ nm}$ , so that the light generation is  $A \exp(-x/a)$ , where  $A = 10^{20}\text{cm}^{-3}\text{s}^{-1}$ . The surface recombination velocity is  $S = 10^5\text{cm/s}$ .
  - (a) What is the distribution of carriers in the sample? Clearly state any assumptions made.
  - (b) What fraction of the generated minority carriers make it to the surface before recombining?
  - (c) What is the electric field distribution in the sample?
  - (d) Justify any assumptions made in your analysis.
2. In silicon, there are actually two hole bands with the same maximum energy. The two bands have different curvatures and are called the heavy and light hole bands. Consider a thin Si membrane just 5 nm thick.
  - (a) Calculate the change in the  $n_i^2$  due to the confinement (ratio of value in membrane to value in bulk normalized for volume).
  - (b) What would be the inverse effective mass tensor for holes in the thin silicon?
3. Consider a layered MOMOS capacitor structure consisting of Si substrate doped with  $N_d = 10^{18}\text{ cm}^{-3}$ , 2 nm of  $\text{SiO}_2$ , 5 nm of Al, another 2nm of  $\text{SiO}_2$  and another 5 nm of Al. Electrodes are attached to the top Al and to the substrate, but the middle Al layer is left floating.
  - (a) If there is no charge on the floating metal gate, calculate the voltage applied between top gate and semiconductor to bring surface of semiconductor to the edge of strong inversion.
  - (b) Repeat for a positive charge on the metal gate of  $10^{13}\text{ C/cm}^2$ .
  - (c) What gate to substrate capacitance would be measured at low frequency at the edge of strong inversion with the charge on the metal? Is the capacitance of the inversion layer significant? Explain.